N89-29882

6.4 THE USE OF DC-PROBE MEASUREMENTS IN THE MIDDLE ATMOSPHERE PROGRAM

E. V. Thrane

Norwegian Defence Research Establishment
P.O. Box 25, N-2007 Kjeller, Norway

The middle atmosphere is weakly ionized, collision dominated plasma. Rocket-borne dc probes have proven effective in measuring conductivity and electron and ion concentrations in this plasma, and in some cases electron temperatures and ion composition have been observed. During MAP, dc probes have also been used successfully to study turbulence in the middle atmosphere, using the plasma as a passive tracer for the dynamical processes in the nonionized gas. The paper will briefly review basic principles of the dc-probe technique and present examples of results obtained during MAP.

Principles of dc Probes

A "dc" or "electrostatic" probe consists of one or more electrodes inserted as diagnostic tools into the plasma to be studied. An electrode is given a potential (positive or negative) relative to a reference, and the current flowing from the plasma to the electrode is measured.

The terms "dc" or "electrostatic" are used in a broad sense to allow "slow" variations of the potential (on time scales larger than any plasma wave phenomenon)

In most applications in the upper atmosphere the space vehicle itself provides the return electrode in the probe circuitry. The currents must satisfy the following relation:

$$\underbrace{I_e}_{\text{electrons}} + \underbrace{I_-}_{\text{negative ions}} + \underbrace{I_+}_{\text{positive ions}} + \underbrace{I_s}_{\text{secondary}} = 0$$

In order to provide a suitable reference potential the probe/payload area must be $< 10^{-3}$.

Measured Parameters:

- Electron density
- Ion density
- Electron temperature
- Conductivity

Types of Probes:

- Screened positive ion probes
- Nose tip or ogival electron probes
- Blunt (patch) probes

The examples are of probes used in MAP.

Experimental characteristics of dc probes

Advantages:

Simple principle and electronic design
Well suited for high resolution *in situ* studies in rocket and balloon payloads

Disadvantages:

Theory complex and difficult to apply
Calibration with other experiments needed to obtain absolute plasma densities
Shock front may influence results
Surface potential difficult to control

Contributions of dc probes to MAP

dc probes have been used extensively to study fine scale structure in the middle atmosphere
From such studies information has been obtained on turbulence and waves that could not easily have been obtained by other means
Combination of such *in situ* studies with ground-based radar and lidar techniques have proved to be a powerful tool in studies of middle atmosphere dynamics as well as the radar reflection mechanisms

Further studies:

Build a data base on middle atmosphere fine scale structure and its variability in time and space
Contribute to the understanding of middle atmosphere waves and turbulence by studying small scales *in situ*
Contribute to the understanding of radar reflection mechanisms in the middle atmosphere
Studies of the microstructure of ion and electron density irregularities in the lower ionosphere

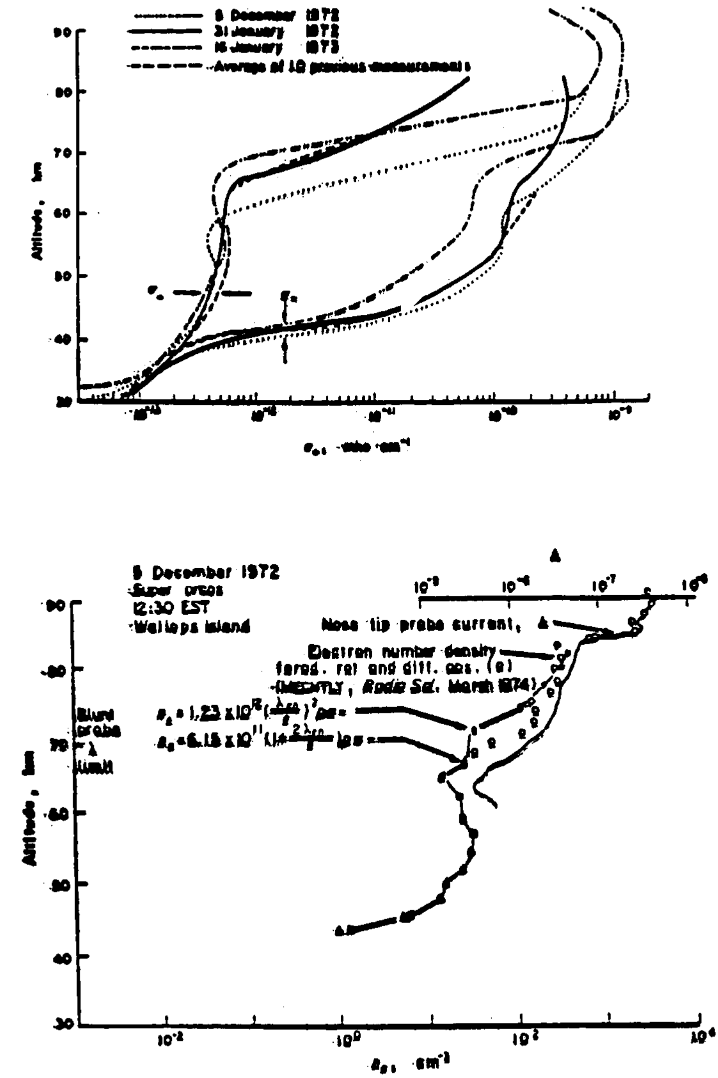


Figure 1. "Classical" use of dc probes. (a) variation of blunt probe conductivity measurements during winter conditions [York et al., 1972], (b) Comparison of height variations of electron density predicted from blunt probe measurements with electron densities from other techniques [York et al., 1982]. The formulae indicated in the figure give the expressions used to derive electron densities from measured conductivities in different height ranges.

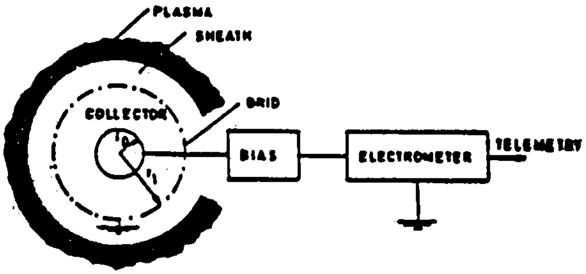


Figure 2. Single grid spherical probe.

Figure 3. Nose tip probe for measuring conductivity during rocket ascent.

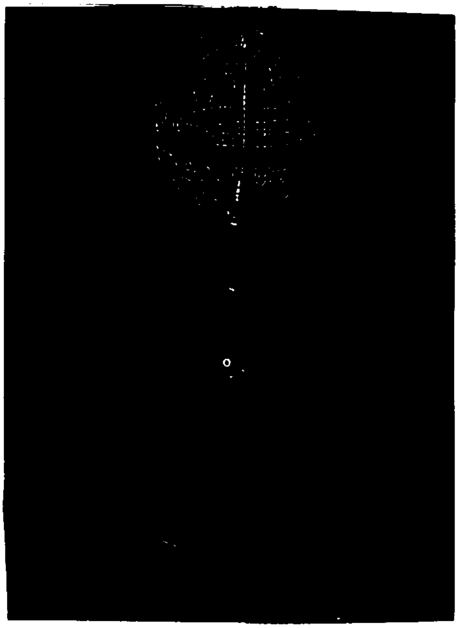
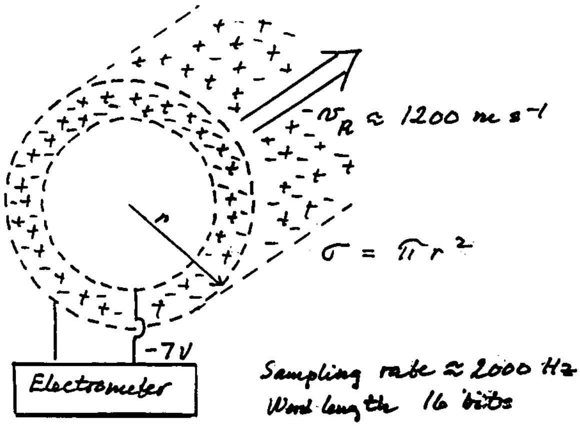


Figure 4. The NDRE positive ion probe flown in MAC/Epsilon.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH



The current measured by the electrometer will be

$$\boxed{I = e N_+ \sigma v_R}$$

Differentiating (σ and $v_R \approx$ constant) yields the fluctuations:

$$\boxed{\frac{\Delta N_+}{\langle N_+ \rangle} = \frac{\Delta I}{\langle I \rangle}}$$

Using the ions as passive tracers we find

$$\frac{\Delta N_+}{\langle N_+ \rangle} \propto \frac{\Delta n}{\langle n \rangle} \Rightarrow \overline{u^2} \Rightarrow K, \varepsilon, \overline{u_i u_j}$$

Measured scale heights | Energy equation | Wave structure

Figure 5. The electrostatic positive ion probe PIP.

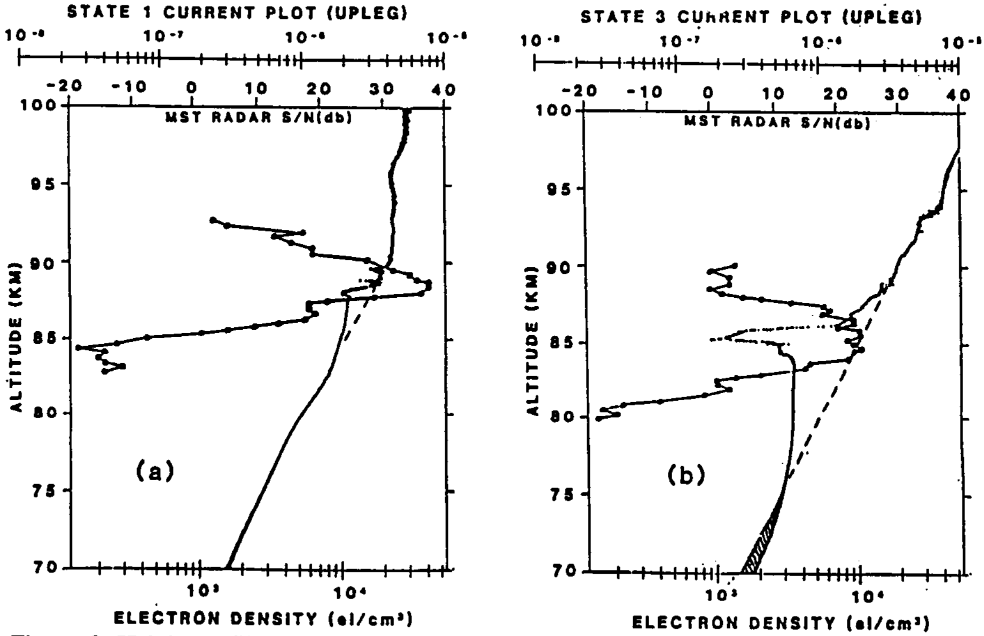


Figure 6. Height profiles of the rocket-borne dc probe results and MST radar echo S/N (solid circles) for the STATE 1 (a) and STATE 3 (b) rocket flights. The dc probe results are given both in probe current (top scale) and tentative electron density values (bottom scale) assuming a constant proportionality between the two. The dashed lines illustrate a more typical D-region profile.

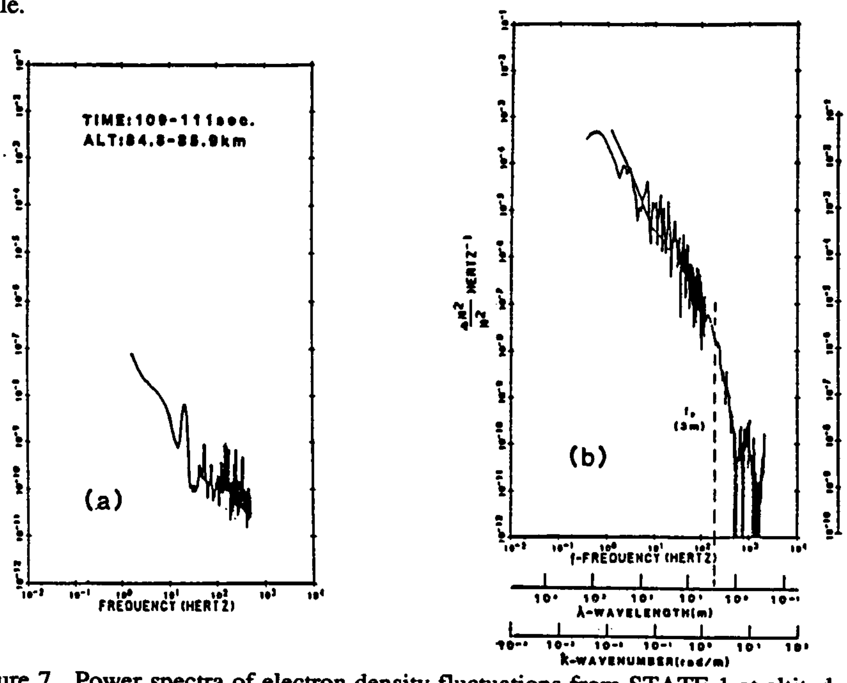


Figure 7. Power spectra of electron density fluctuations from STATE 1 at altitudes where radar echo S/N is the weakest (a - 85 km) and strongest (b - 88 km).

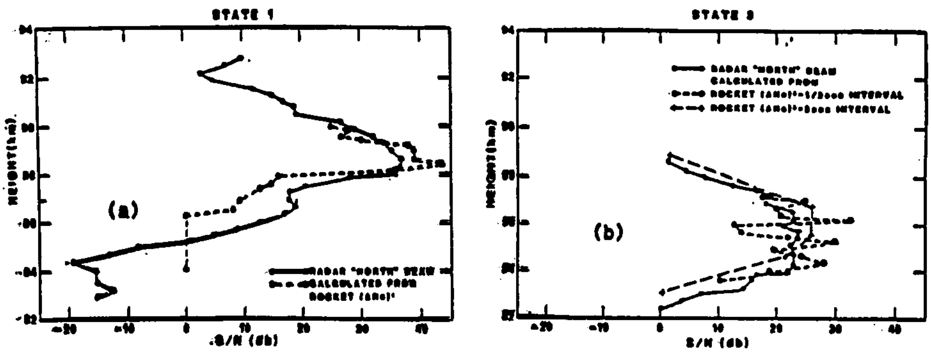


Figure 8. MST radar echo power (S/N measured by the north beam and calculated from the high resolution electron density power fluctuations measured by the rocket probes: STATE 1 results (a) and STATE 3 results (b).

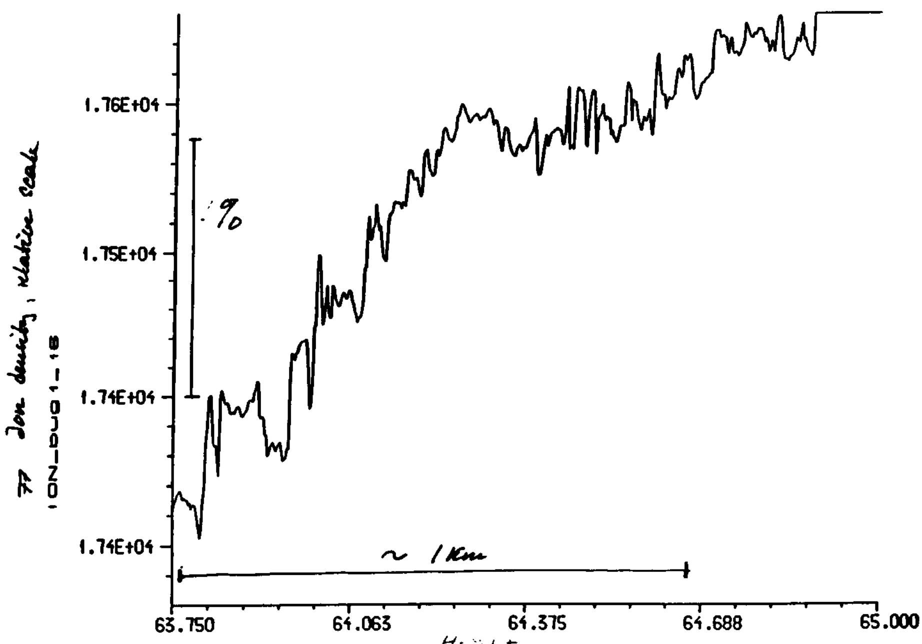


Figure 9. Examples of PIP results from MAC/Epsilon.

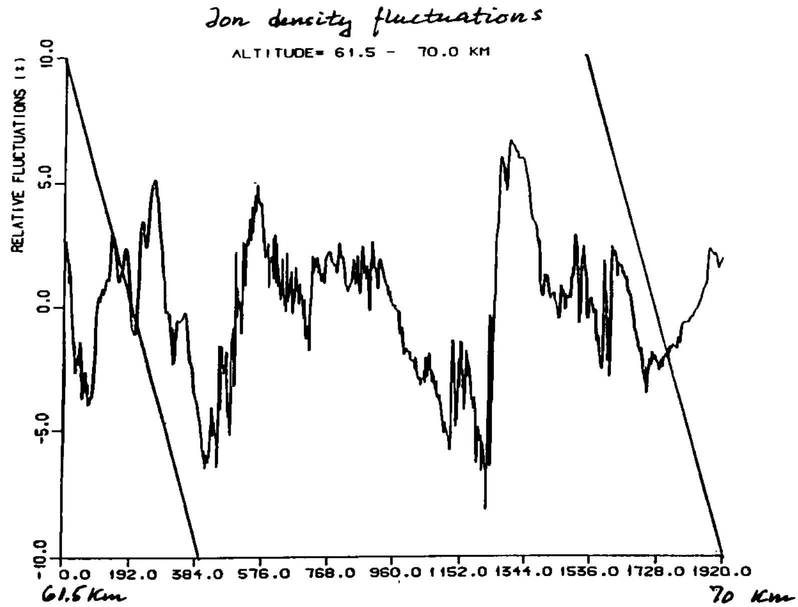


Figure 10. Examples of PIP measurements from MAC/Epsilon.

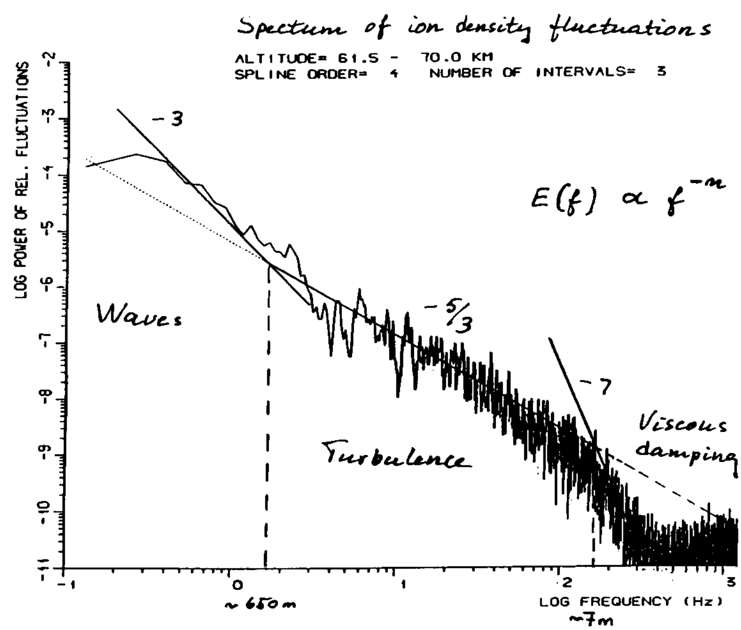


Figure 11. Spectrum from Figure 10.